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Ecological studies of microarthropods in a New Zealand pasture soil with special reference to the Collembola (I.)

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With 4 figures

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1. Introduction

Much work has been done on soil microarthropods in Britain, continental Europe and North America. Information regarding these soil animals would seem to be of particular importance in an agricultural country such as New Zealand but up to the present time investigations have been mainly of a systematic nature and there are few published records of community studies on soil microarthropods in this country. This study was therefore directed towards an ecological investigation of the Acari and Collembola of a New Zealand grassland soil. Concurrently with the present study McMillan (1969) made a comparison of the microarthropods in two grassland soils situated at the Soil Bureau, Taita, New Zealand.

Samples of a pasture soil were taken to a depth of 18 cm, and collected regularly throughout a 12 month period, with the object of gaining information on species composition and population dynamics in the soil profile during the annual cycle. To supplement the field data, several dominant species of Collembola were bred in the laboraratory and observations made on growth and oviposition rates, and feeding habits. This is the first paper of several planned to present the results of these studies, and contains check lists of Acari and Collembola recorded from the Akatarawa pasture, Frequency and Dominance values of species, population density during the annual cycle, and an investigation of species association within the plot. Comparisons are made with results from other grasslands in Britain and continental Europe.

2. Description of Habitat

The chosen site is part of an established farm in the Akatarawa hills about 80 kilometres north of Wellington, New Zealand, Lat. 41° S. Long. 175° E. The farm is situated among steeply rolling hills, 166 metres above sea level, in a moderately well drained silty clay loam, lying over deeply weathered greywacke, and classified as an Akatarawa hill soil by Gibbs (1960). Grid Ref. N. 157, 628. 669.

The area receives a high rainfall (65.76 ins. — 1670.3 mm, Sept. 1964 to Aug. 1965). Rainfall is mainly in autumn winter and spring with usually a marked dry season extending from about the end of December to March. The climate is warm temperate and the habitat is not subject to snow (temperatures at ground level during sampling visits ranged from 11.1 °C to 27.8 °C).

The soil has a good crumb structure, about average organic content for a mineral type soil, and is uniformly acid, *p*H 5.2.

The pasture is used mainly for grazing sheep and cattle, and has not been ploughed or treated with fertilizers or pesticides for more than ten years.

The original cover, which from the surrounding remnants of native forest is thought to have consisted predominantly of rimu, (*Dacrydium cupressinum* Soland.), miro (*Podocarpus ferrugineus* D. Don.) and kamahi (*Weinmannia racemosa* Linn.), was felled and burned about 100 years ago and the area sown to grass. The dominant plant in the pasture is now brown top (*Agrostis tenuis* Sibth.) which forms a dense turf over much of the area.

3. Methods

A rectangular plot measuring 30 × 12 m subdivided into 10 subplots each measuring 6 × 6 m was set out on a flattened ridge which runs approximately north and south in the paddock.

From September 1964 to August 1965 a sample was collected from the field between the 23rd and 28th days of each month. A sample consisted of 10 units, each taken at random from one of the subplots. The samples were taken using a cylindrical brass tool 7 cm in diameter and 60 cm long, provided with a removable cutting head of slightly smaller diameter than the cylinder. This enabled the sample to slide easily from the cylinder when the head was removed. Each unit was divided transversely into four sections, the top section 3 cm and each of the others 5 cm deep. The 40 subunits were extracted separately in a multiple type Tullgren apparatus and left in the funnels for seven days. The collections were stored in a mixture of 75% alcohol and glycerine (95 : 5). Polyvinyl lactophenol M.A. 1., (Salmon 1955) was used for clearing and mounting specimens on microscope slides. From separate soil cores taken from immediately beside each of the sample unit cores, moisture content was determined at upper and lower levels in the soil profile to 18 cm. The soil was dried in an oven at 105 °C. for three days and percentage moisture content calculated as $\frac{\text{weight of moisture}}{\text{weight of dry soil}} \times 100$. Rainfall was measured by a rain gauge installed at the site, and readings were made once a month during the sampling visit. Temperature of the air at ground level and at 3—5 cm in the soil was recorded at each visit.

The classification of the Collembola follows that of Salmon (1964). For the Cryptostigmata, Balogh (1965) was used, and for the Mesostigmata, Prostigmata and Astigmata the following were used; Evans et al., (1964) and Baker and Wharton (1964). All Collembola were identified to species level, but as the mite fauna of New Zealand is relatively unknown, taxonomic determination of some species was not done beyond that of genus or in some cases family level.

4. Results

4.1. Qualitative composition

During the 12 months of sampling 25 species of Collembola and 39 species or other taxa of Acari were recorded. Check lists of the Collembola and Acari together with numbers of individuals collected during the year are given in Appendixes 1 and 2. Total numbers of the four Orders of Acari and three Sub-orders of Collembola expressed as percentages of the total microarthropod population are given in Appendixes 3 and 4. Numbers include adults and juveniles for all groups. Numbers of total microarthropods, Acari and Collembola and their constituent Orders and Sub-orders, are shown graphically in Figs. 2—4. Rainfall recorded at the site, and percentage moisture content at 0—9 cm and 9—18 cm in the soil profile are shown in Figs. 1 A., B.

The Acari (App. 1) belong mainly to cosmopolitan species. The Cryptostigmata *Hypochthonius luteus*, *Brachychthonius jugatus* var. *suecica*, *Platynothrus peltifer* and *Punctoribates punctum* which are listed as cosmopolitan, have not been recorded outside New Zealand in the Southern Hemisphere (Hammer 1968).

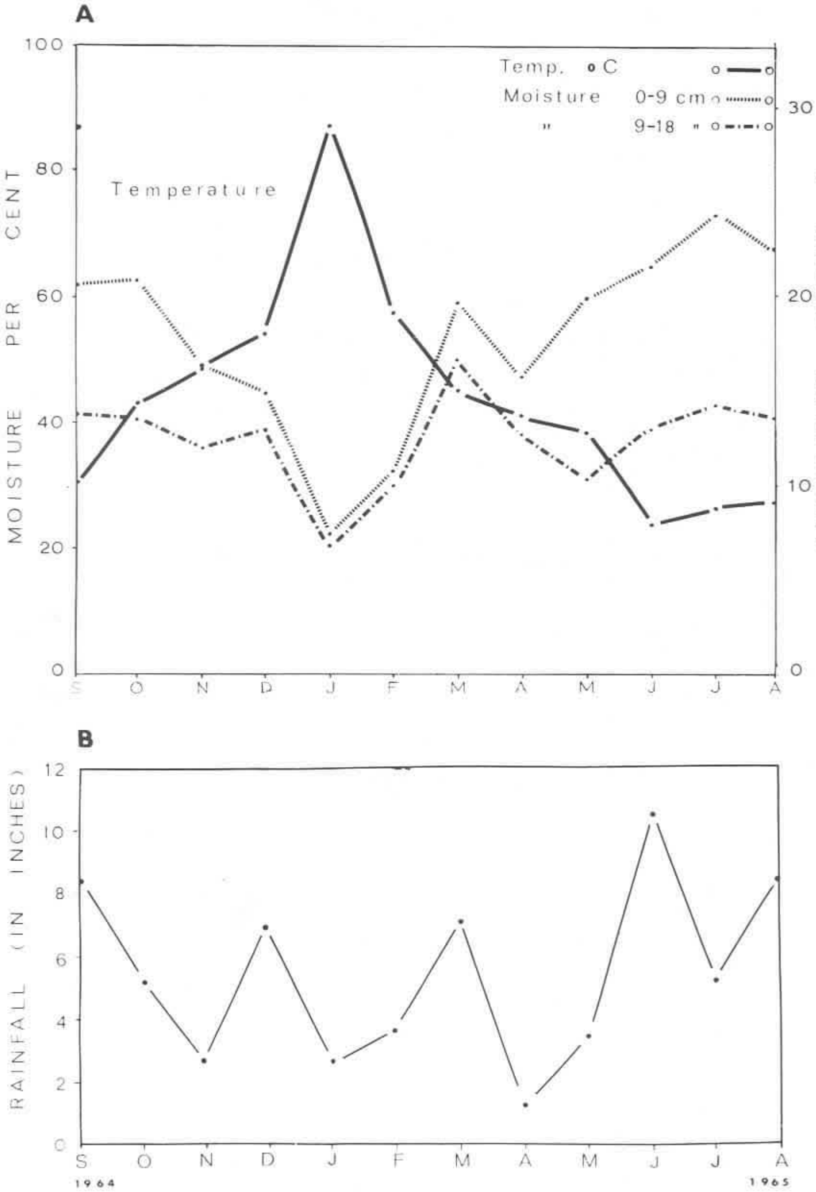

Fig. 1. Hygrothermic regime at Akatarawa from September 1964 to August 1965.
(A) Percentage soil moisture content at 0–9 cm and at 9–18 cm in the soil profile.
(B) Rainfall.

The Collembola (App. 2) comprise 15 cosmopolitan species, six endemic species, and four with relationships mainly with North America and Europe. Two new species of Collembola *Morulina* n. sp. *Megalothorax* n. sp., were recorded from the habitat and five Collembola, (*Hypogastrura guthriei* Folsom, *Folsomia candida* Willem, *Friesea mirabilis* Tullberg, *Sphaeridia serrata* Folsom and Mills, *Sphaeridia pumilis* (Krausbauer) are recorded for the first time from New Zealand.

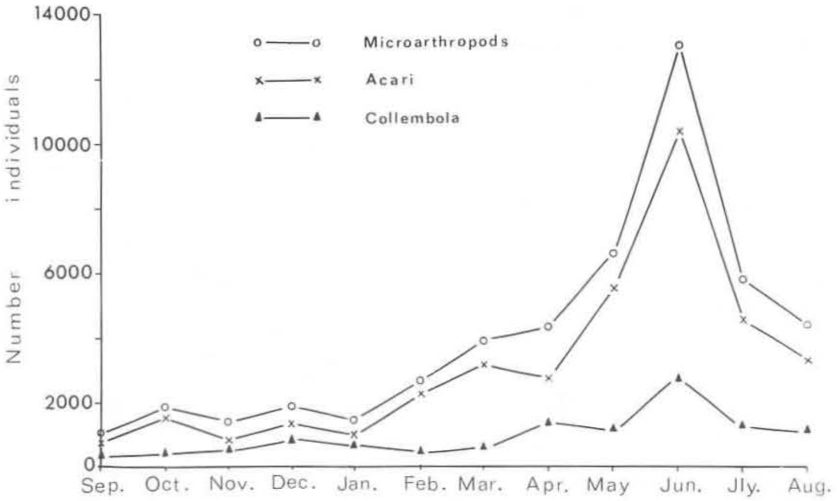

Fig. 2. Total numbers of microarthropods, Acari and Collembola recorded from 12 samples taken September 1964 to August 1965.

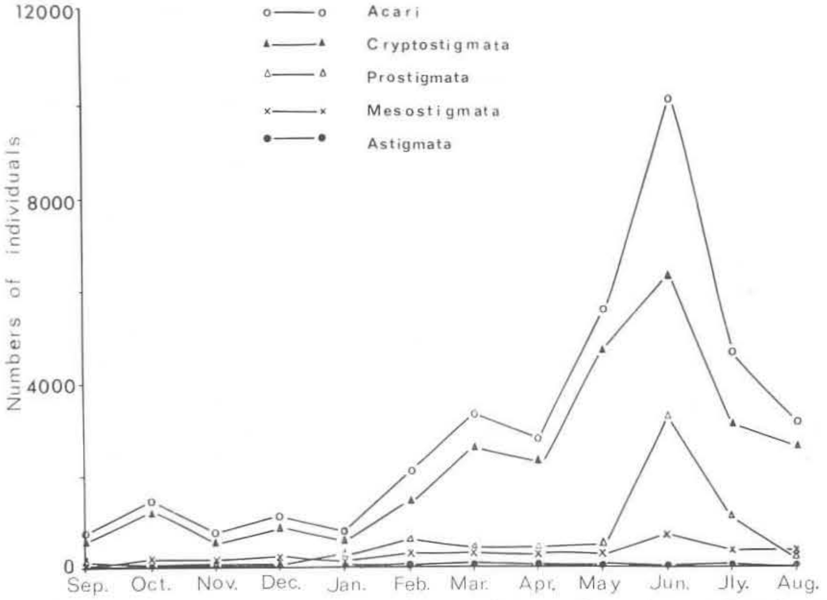

Fig. 3. Total numbers of Acari and the Orders Cryptostigmata, Mesostigmata, Prostigmata and Astigmata recorded September 1964 to August 1965.

4.2. Quantitative composition

The mean microarthropod population density during a 12 month period to a depth of 18 cm was 100,647 per square metre, the numbers ranging from a minimum of 23,918 per square metre in September to a maximum of 329,429 in June.

The Acari forming 77.7% of total individuals dominated the microarthropod population. The most numerous mites were the Cryptostigmata which accounted for 73.3%

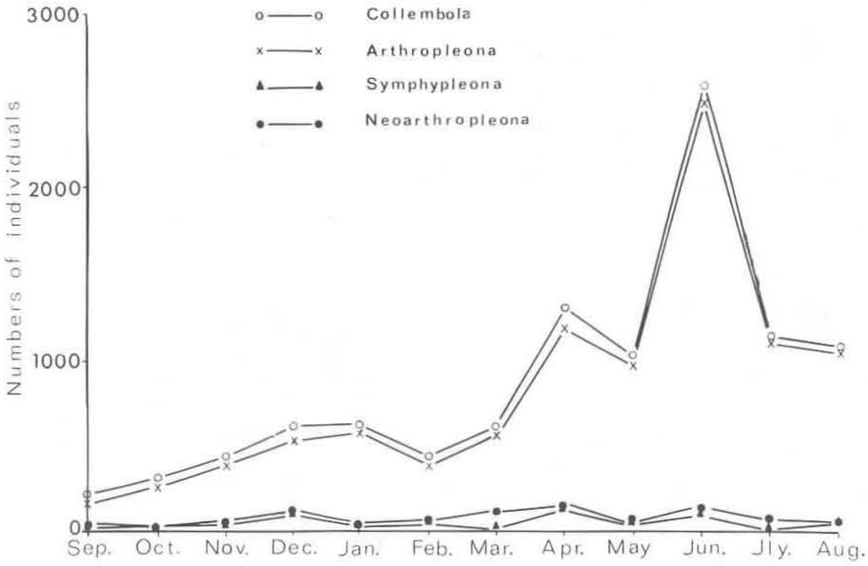

Fig. 4. Total numbers of Collembola and the Suborders Arthropleona, Symphypleona and Neoarthropleona recorded September 1964 to August 1965.

of the total Acari and 57.1% of the total microarthropods. Of the 39 species or other taxa of Acari identified from the plot, 14 were Prostigmata, 11 Cryptostigmata, 13 Mesostigmata and one belonged to the Astigmata. A total of 36,157 individuals were collected from the 120 cores, and the estimated mean number per square metre was 78,250 to a depth of 18 cm (App. 3). During the year numbers fluctuated from 18,984 in September to 262,453 per square metre in June.

The Collembola with a total of 10,349 individuals collected on the 12 sampling occasions, made up 22.3% of the microarthropod population giving an estimated mean number of 22,397 per square metre, to a depth of 18 cm. Collembolan numbers also fluctuated seasonally ranging from 4,934 in September to 66,976 in June. The Arthropleona were numerically the largest collembolan group, comprising half the species and 88% of the individuals. The Neoarthropleona were represented by three species, *Brachystomella parvula*, *Friesea mirabilis* and *Morulina* n. sp. The first of these occurred abundantly in the habitat and was present throughout the annual cycle. The other two species occurred only rarely at the site. Total Acari exceeded total Collembola by about 1.4 : 1 in January (summer) and 5.2 : 1 in May (autumn-winter), giving a mean of about 3.5 : 1 over the year.

5. Distribution in the habitat

5.1. Frequency and dominance of microarthropods

For the purpose of investigating the relative importance of the different species of mites and Collembola in the microarthropod community, estimates were made of their Frequency and Dominance values. Frequency was calculated by expressing the number of samples in which a species occurred as a percentage of the total number of samples. Dominance, was expressed using the number of individuals of a particular species as a percentage of the total numbers of individuals of all species. In order to show more clearly the relative contributions made to the fauna by the main species of Acari and Collembola, a system of grouping was used, first suggested by WEIS-FOGH (1947—48) in which species are grouped into classes on the basis of Frequency and Dominance values. DAVIS (1962, p. 55) combined the two groupings given by WEIS-FOGH in

Table 1 The most abundant and frequently occurring species of Acari and Collembola at the Akatarawa pasture arranged in frequency groups or constancy classes, and listed in order of Dominance

	Dominant	Influent
Constant	*Oppia* spp. *Platynothrus peltifer* *Isotomina thermophila* *Protophorura armata* *Hypogastrura guthriei* *Mesaphorura krausbaueri* *Brachystomella parvula*	*Tydeus* sp. *Brachychthonius jugatus* var. *suecica* *Scutovertex sculptus* *Rhodacarellus silesiacus* *Tectocepheus velatus* *Punctoribates punctum*
Accessory		*Hypogastrura armata* *Hypogastrura manubrialis* *Entomobrya nivalis* *Isotomurus palustris* *Sphaeridia serrata*

Dominant = species 5% or more of total individuals
Influent = species 2–5% of total individuals
Constant = species occurring in more than 50% of samples
Accessory = species occurring in 25–50% of samples

a two-way classification and gave higher values for the degrees of Dominance. In Table 1, DAVIS' grouping has been used, but the values for Dominance suggested by WEIS-FOGH have been retained.

The species with the greatest abundance tend to have the highest Frequency of occurrence. There were exceptions however. In some of the samples, several species, including *Hypogastrura armata*, *Entomobrya nivalis* and *Isotomurus palustris* showed local concentrations with consequently high density averages, although the Frequency values were lower than 50. On the other hand species such as *Folsomia candida* (Collembola) and *Totobates* sp. (Acari) had comparatively high Frequency percentages in spite of their low density.

Two Cryptostigmata (*Oppia* spp., *Platynothrus peltifer*) and five Collembola, (*Isotomina thermophila*, *Protaphorura armata*, *Hypogastrura guthriei*, *Mesaphorura krausbaueri* and *Brachystomella parvula*) are shown to be the most numerous, and most frequently occurring species in the habitat. A further group of six Acari are also frequently present at the site (50—100% of cores) but are of only moderate Dominance (2—5% of all individuals). This group includes one Prostigmata (*Tydeus* sp.) one Mesostigmata (*Rhodacarellus silesiacus*), and four Cryptostigmata, (*Brachychthonius jugatus* var. *suecica*, *Scutovertex sculptus*, *Tectocepheus velatus*, *Punctoribates punctum*). It is evident from the results that in general the Cryptostigmata are more numerous and more widely distributed through the plot, than either the Mesostigmata or the Prostigmata. The two latter groups with a few exceptions e. g. *Rhodacarellus silesiacus* and *Tydeus* sp. do not attain Dominance and occur sporadically in the Akatarawa pasture.

5.2. Species association

5.2.1. *General remarks*

Considerable variation was noted in the frequency of occurrence and relative abundance of microarthropod species in the sampling units. Certain specis were found to occur regularly and abundantly in the same soil cores while others were rarely if ever found together. It seemed that an investigation of such co-occurrences, or group associations within the plot might provide useful information on community organization, for, as DAVIS (1962) observed, "the essence of community ecology rests on the conviction that the presence and relative abundance of a number of species in a circumscribed area means that they must not only have certain requirements in common, but be able to live successfully with each other".

DEBAUCHE (1962) suggests a technique for finding the degree of association between species based on the co-occurrences of species in sample units. The method has since been used by a number of soil zoologists including DAVIS (1962) and LUXTON (1964).

The data is tabulated in contingency form:

		Species 1		
		Present	Absent	
Species 2	Present	a	b	$a + b$
	Absent	c	d	$c + d$
		$a + c$	$b + d$	$a + b + c + d = n$

In the contingency table, *a*, *b*, *c* and *d* are the terms of two species, *a*, being the number of times both species are present, *d* the number of times neither are present, and *b* and *c* the numbers of times when only one species is present.

The significance of association of species is tested by comparing the observed frequencies with those expected by a contingency χ^2 test.

$$\chi^2 = \frac{n(|\,ad - bc\,| - {}^1/_2 n)^2}{(a + c)\;\;(b + d)\;\;(c + d)\;\;(a + b)}$$

The actual degree of association is given by:

$$C = \sqrt{\left(\frac{\chi^2}{n + \chi^2}\right)}.$$

The correlation coefficient was calculated for eight species of Acari and eight species of Collembola which occurred with a high frequency at the sampling site. The presence or absence of the 16 species in the 120 cores was first recorded. The values for *a*, *b*, *c* and *d* were then obtained from this table, and the values of χ^2 found for each species, paired with each of the other 15 species. Values of χ^2 over 6.63 are significant at the 1% level and those between 6.63 and 3.84 are significant at the 5% level, with one degree of freedom. The correlation coefficient C was then found and the nature of the association, positive or negative, obtained from the sign of the expression *ad*−*bc*. The species were then combined into groups showing the greatest mutual association (see Table 2).

5.2.2. *Results*

The results are given in Table 2. Of the 120 terms, 85 were positive and 35 negative. Twenty two were significant and of these, 21 were positive and only one was negative. One strong group association of species within the site is evident. This occurs between *Rhodacarellus silesiacus* [Mesostigmata], *Brachychthonius jugatus* var. *suecia* [Cryptostigmata], *Hypogastrura armata* [Collembola], *Tectocepheus velatus* [Cryptostigmata] and *Mesaphorura krausbaueri* [Collembola]. This group of five species which includes one predaceous mesostigmatid (*R. silesiacus*) were all positively significantly associated with each other. The highest recorded positive index between species is that found between *Brachychthonius jugatus* var. *suecica* and *Hypogastrura armata*. The former species is also strongly associated with *Tectocepheus velatus* and *Mesaphorura krausbaueri*. *Tectocepheus velatus* appears to be widely distributed in the plot and shows many affinities outside the main group, notably with *Platynothrus peltifer*, *Totobates* sp. and *Entomobrya nivalis*. *Isotomina thermophila* and *Hypogastrura guthriei*, which occur with high frequency in the area, are associated with each other, but, apart from a possible predator-prey relationship between the latter species and *Rhodacarellus silesiacus*, they do not form any significant relationships with other species in the plot. Another direct predator-prey link seems to be indicated between *Cosmolaelaps communis* and the Collembola *Isotomurus palustris* and *Hypogastrura armata*.

It has been observed by other workers (DAVIS 1962, LUXTON 1965) that significant positive associations can be interpreted in several ways. Two species may be associated because they share the same food resources or require similar microclimates. Animals

Table 2 The Microarthropod Associations of the Akatarawa Site

	R. silesiacus	*B. jugatus*	*H. armata*	*T. velatus*	*M. krausbaueri*	*H. guthriei*	*S. thermophila*	*B. parvula*	*P. armatus*	*I. palustris*	*E. nivalis*	*P. punctum*	*P. peltifer*	*Totobates* sp.	*S. sculptus*	*C. communis*
Rhodacarellus s.		254	225	202	185	184	34	30	184	53	96	3	18	120	1	59
Brachychthonius j.	**		435	412	251	38	46	36	2	202	109	101	27	281	126	72
Hypogastrura a.	*	**		264	208	144	40	144	41	3	3	2	18	47	89	184
Tectocepheus v.	*	**	**		205	3	27	126	143	7	213	134	281	281	164	6
Mesaphorura k.	*	**	*	*		55	48	32	81	19	14	69	40	55	52	3
Hypogastrura g.	*	+	+	+	+		221	33	66	24	7	28	26	82	5	24
Isotomina t.	+	+	—	—	+	*		26	64	30	2	26	205	30	41	64
Brachystomella p.	+	+	+	+	+	—	—		36	33	35	5	136	106	139	102
Protaphorura a.	+	+	+	+	+	+	—	+		63	50	68	103	14	37	76
Isotomurus p.	—	*	+	—	+	—	+	+	+		64	69	10	147	51	234
Entomobrya n.	—	+	—	*	+	—	+	+	+	—		194	59	74	142	109
Punctoribates p.	—	+	—	+	+	—	—	—	+	+	*		23	360	81	194
Platynothrus p.	+	+	+	**	+	+	!	—	+	+	—	+		6	71	7
Totobates sp.	+	**	+	**	+	+	—	—	—	—	+	**	+		20	76
Scutovertex s.	—	+	+	+	+	—	—	+	+	+	+	+	—	+		56
Cosmolaelaps c.	—	—	*	+	—	—	—	—	+	**	+	+	+	+	—	

Figures denote C×10³

Positive at 1 % level	**	Negative at 1 % leval	!!
Positive at 5 % level	*	Negative at 5 % level	!
Positive but insignificant	+	Negative but insignificant	—

may also be associated because of a predator-prey relationship. The simultaneous occurrence of two species, however, does not necessarily imply a direct relationship between the two, as different food resources or other requirements may be associated in the same soil core.

It is difficult to say whether the two Cryptostigmata, *Brachychthonius jugatus* var. *suecica*, *Tectocepheus velatus* and the two Collembola *Hypogastrura armata*, *Mesaphorura krausbaueri*, require the same physical and chemical factors in the soil for their existence, or whether they are associated because they share a particular food supply. As many Collembola and Acari are considered to be unspecialized feeders but appear to have exacting requirements of soil micro-climate, it would seem likely that species associations might be based very largely on the physical and chemical nature of the soil. It is possible therefore that this group association of five species is based mainly on the micro-climate of the soil, and that *Rhodacarellus silesiacus* is attracted into the group because of its predaceous feeding habits.

6. Comparison with other habitats

Table 3 summarizes studies of the microarthropods of eight different grassland soils in continental Europe and Britain, and the Akatarawa site. The types of soil investigated varied widely from a light well drained loam (DHILLON and GIBSON 1962), through a heavy clay (DAVIS 1962) to a heavy wet loam (SHEALS 1957). It is also seen that different workers used different methods of extraction which were no doubt of greatly varying efficiency. Another difficulty in making quantitative comparisons arises from sampling not being continued through the entire annual cycle. Results therefore do not take into account the seasonal fluctuations in density which are characteristic of grassland soil populations. SHEALS (1957) sampled only during months when population numbers might be expected to be high and SALT et al. (1948/49) based their estimates on the results of one sampling occasion only. In some cases therefore, the figure given is that of a mean for the annual cycle, while in others it is possibly a maximum for that particular site. Many of these results therefore are not directly comparable, but from the figures available the Akatarawa fauna appears to be of about average density, but the maximum recorded in June is higher than any recorded from the British and European grasslands.

Comparison with the species lists from these grasslands shows very little similarity with that from the Akatarawa. Very few Collembola are common to all the habitats but there appears to be a small group of species including *Protaphorura armata*, *Mesaphorura krausbaueri* and *Friesea mirabilis* which occurs with great regularity at the different sites. The two latter species occur in eight of the nine sites and the former in seven of the nine sites. The closest similarity in species composition with the Akatarawa seems to be the pasture of Davis' site 0 on a heavy clay soil. Collembola in common with this site included *Brachystomella parvula* and the hygrophilous species *Isotomurus palustris*. The former species was Dominant at the Akatarawa site, but was not found commonly in other grasslands.

Species lists of Acari were given in only eight of these investigations but here again there were no close similarities with the Akatarawa fauna. Two Cryptostigmata, *Punctoribates punctum* and *Tectocepheus velatus*, were recorded from six of the eight sites. The Cryptostigmata *Platynothrus peltifer* a Dominant species at the Akatarawa, was recorded from the wet sector only of WEIS-FOGH's transect. *P. peltifer* is generally regarded as a typically hygrophilous species, WEIS-FOGH (1947/48) stating that it occurs only in constantly wet habitats. The Akatarawa pasture however, although receiving a high annual rainfall, is subject to low precipitation during summer months when soil moisture may fall very low. The habitat therefore could not be described as permanently wet, and yet

Table 3 Summary of results from studies on eight grassland soils in Europe and Britain and from the Akatarawa in New Zealand. Species in common with the Akatarawa and each of the other sites are shown

Author	Habitat	Soil type	Microarthr. Total 1000/m²	Method of Extraction	Species in common with Ak. pasture	
					Collembola	Acari
Salt et al. (1948–1949)	old pasture, Cambridge, England	clay loam	263	Flotation (0.1 mm mesh)	*H. armata* *P. armata* *M. krausbaueri*	—
Macfadyen (1952)	Molinia fen, Oxford, England	organic peat	204	Modified Tullgren funnel	*P. armata* *M. krausbaueri* *F. mirabilis*	*T. velatus*
Haarløv (1960)	"level pasture" Denmark	mod. dry sandy loam	288	Tullgren funnel	*P. armata* *M. krausbaueri* *F. mirabilis*	*T. velatus* *P. peltifer* *H. luteus*
Weis-Fogh (1947–1948)	old pasture Denmark	sandy soil gradient from wet to dry	32	Berlese funnel	*H. armata* *B. parvula* *M. krausbaueri* *F. mirabilis*	*T. velatus* *P. punctum* *P. peltifer*
Sheals (1957)	old grassland, Glasgow, Scotland	heavy wet loam	57	Flotation (0.15 mm mesh)	*B. parvula* *F. mirabilis* *F. candida* *I. palustris* *M. krausbaueri*	*P. punctum* *S. sculptus*
Dhillon and Gibson (1962)	old pasture, Leeds, England	light well drained sandy loam	58	Tullgren funnel	*P. armata* *H. armata* *F. mirabilis*	*P. punctum* *R. silesiacus*
Davis (1962)	excavation (site 0) Northamptonshire, England	heavy clay	35	Flotation (0.15 mm mesh)	*P. armata* *H. krausbaueri* *I. palustris* *F. mirabilis* *B. parvula* *I. minor* *A. caecus*	*T. velatus* *P. punctum* *R. silesiacus*
Davis (1963)	old pasture (100)	heavy clay	36	Flotation (0.15 mm mesh)	*P. armata* *M. krausbaueri* *I. palustris* *F. mirabilis* *I. minor* *S. pumilis*	*T. velatus* *P. punctum* *R. silesiacus*
Adams (1964–1965)	Akatarawa pasture New Zealand	silty clay loam	100	Tullgren funnel		

Note: Table in part after Wood (1966).

P. peltifer was a Dominant species at the site. It seems however, that this apparent contradiction is related to the moisture requirements of the different developmental stages in the life cycle of the species. Phenological data from the Akatarawa (Adams in prep.) suggest that the adult *P. peltifer* is relatively drought hardy while the nymphal stage, which requires a constantly wet environment (Michael 1887) is completed before the onset of the dry season. The habitat therefore need not necessarily be permanently wet.

Species lists of mites and Collembola from pasture soils (including a silt loam) at the Soil Bureau, Taita, are given by McMillan (1969). Taita is only about 35 kilometres from the Akatarawa pasture but at Taita, rainfall is lower and is fairly evenly distributed throughout the year (Soil Bureau mean annual: 52.1 ins.- 1323.34 mm; Akatarawa, range 60—70 ins. — 1524—1778 mm). A close similarity with the Akatarawa species is evident. The collembolan *Isotomina thermophila* and the Cryptostigmata, *Oppia* spp., *Platynothrus peltifer*, are Dominant at both Taita and Akatarawa. *Hypogastrura* species are well represented in all habitats, but *Protaphorura armata* and *Mesaphorura krausbaueri* which occur abundantly at Akatarawa do not attain Dominance at Taita.

It seems that the Collembola, *Protaphorura armata*, *Hypogastrura armata*, *Mesaphorura krausbaueri*, *Friesea mirabilis*, and the Cryptostigmata, *Punctoribates punctum*, *Tectocepheus velatus*, occur in most grassland soils, and are capable of adapting to diverse environmental conditions. If the habitats are predominantly wet, the hygrophilous species *Isotomurus palustris* and *Platynothrus peltifer* may also occur. *Friesea mirabilis* although widely distributed in European soils, was found only rarely at the Akatarawa and appeared to be unable to establish in significant numbers.

7. Summary

A census during 1964/65 of the Acari and Collembola in a permanent grassland in the Akatarawa hills, about 80 kilometres north of Wellington, New Zealand showed 25 species of Collembola and 39 species or other taxa of Acari. From regular samples taken throughout a 12 month period, values of Frequency, Dominance and population density were calculated. Seasonal fluctuations in density were found, with peak populations in most species occurring in autumn-winter. A mean total microarthropod population of 100,645 per m^2 to a depth of 18 cm was recorded.

Two Cryptostigmata, (*Oppia* spp., *Platynothrus peltifer*) and five Collembola, (*Isotomina thermophila*, *Protaphorura armata*, *Hypogastrura guthriei*, *Mesaphorura krausbaueri*, *Brachystomella parvula*) were the most abundant and frequently occurring species in the habitat. A strong group association of three Cryptostigmata, (*Brachychthonius jugatus* var. *suecica Tectocepheus velatus*, *Rhodacarellus silesiacus*) and two Collembola (*Hypogastrura armata*, *Mesaphorura krausbaueri*) occurs within the plot. Little similarity is found in species composition with results from eight British and continental European grassland studies, but a close similarity is found with the microarthropods recorded from two pasture soils located at the Soil Bureau, Taita, New Zealand.

7. Zusammenfassung

Eine 1964 bis 1965 durchgeführte Untersuchung der Milben und Collembolen in einem Weidenboden, in den Akatarawa-Bergen, rund 80 km nördlich von Wellington, zeigte 25 Collembolenarten und 39 Arten oder andere Taxa von Milben, Von den während einer 12monatigen Periode regulär entnommenen Proben wurde die Frequenz, Dominanz und Abundanz errechnet. Es wurden jahreszeitliche Fluktuationen, mit Abundanz-Maxima der meisten Arten im Herbst und Winter, gefunden. Ein durchschnittlicher Gesamtbesatz der Mikroarthropoden von 100645 Ex./m^2/18 cm Tiefe wurde ermittelt.

Zwei Cryptostigmata (*Oppia* spp. und *Platynothrus peltifer*) und fünf Collembola (*Isotomina thermophila*, *Protaphorura armata*, *Hypogastrura guthriei*, *Mesaphorura krausbaueri* und *Brachystomella parvula*) waren die zahlreichsten und am häufigsten im Habitat vorkommenden Arten.

Eine starke Gruppenbindung von 3 Cryptostigmata (*Brachychthonius jugatus*. var. *suecia*, *Tectocepheus velatus* und *Rhodacarellus silesiacus*) und zwei Collembolen *Hypogastrura armata*, *Mesaphorura krausbaueri*) zeigte sich innerhalb der Untersuchungsparzelle. Wenig Ähnlichkeit

in der Artenzusammensetzung zeigte sich mit 8 britischen und kontinental-europäischen Grasland-Untersuchungen, aber eine starke Ähnlichkeit wurde mit dem Mikroarthropodenbesatz zweier Weidenböden in der Nähe vom Soil Bureau Taita, Neuseeland, gefunden.

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10. Check lists and synoptical tables (Appendices 1–4)

Appendix 1 Check list and distribution of Acari at the Akatarawa site

Species	Distribution	No. individuals	Sampling occasions											
Order: Cryptostigmata			1	2	3	4	5	6	7	8	9	10	11	12
Platynothrus peltifer Koch, 1839	cosmopolitan	4,444	+	+	+	+	+	+	+	+	+	+	+	+
Platynothrus skottsbergii Trägårdh, 1931	Juan Fernandez, N. Z.	43	+	+	–	–	–	–	–	–	–	–	–	+
Punctoribates punctum (Koch, 1839)	cosmopolitan	528	+	+	+	+	+	+	+	+	+	+	+	+
Tectocepheus velatus Michael, 1880	cosmopolitan	1,840	+	+	+	+	+	+	+	+	+	+	+	+
Totobates sp. (Oudemans, 1906)	S. America, N. Z.	589	+	+	+	+	+	+	+	+	+	+	+	+
Brachychthonius jugatus Jacot, 1938. var. *suecica* Forsslund, 1938	cosmopolitan	1,661	+	+	+	+	+	+	+	+	–	+	–	+
Hypochthonius luteus Oudemans, 1913	cosmopolitan	450	–	–	–	+	+	+	+	+	–	–	–	+
Scutovertex sculptus Michael, 1879	cosmopolitan	846	+	+	+	+	+	+	+	+	+	+	+	+
Zygoribatula terricola van der Hammen, 1952	Netherlands, Israel, N.Z.	4	–	–	–	–	–	+	+	+	–	–	–	–
Microtritia sp. Perty, 1841	cosmopolitan	4	–	–	–	+	–	+	–	–	+	–	–	–
Oppia spp. Koch, 1836	cosmopolitan	17,105	+	+	+	+	+	+	+	+	+	+	+	+
Order: Mesostigmata														
Rhodacarellus silesiacus Willman, 1936	cosmopolitan	1,515	+	+	+	+	+	+	+	+	+	+	+	+
Cosmolaelaps communis Trägårdh, 1931	Juan Fernandez, N.Z.	182	+	+	+	+	+	+	+	+	+	+	+	+
Androlaelaps queenslandicus Womersley, 1956	Australia, N.Z. N. America	89	+	+	+	+	+	+	+	+	+	–	–	+
Ololaelaps sp. Berlese, 1903	cosmopolitan	75	+	+	+	+	–	+	+	+	+	+	+	+
Asca sp. Oudemans, 1905	cosmopolitan	60	–	+	+	+	+	+	+	+	–	+	–	–
Arctoseius sp. Thor, 1930	cosmopolitan	58	–	+	+	+	+	+	+	–	–	–	–	–

Sampling occasions: 1, 28th Jan. 1965; 2, 25th Febr. 1965; 3, 27th Mar. 1965; 4, 25th Apr. 1965; 5, 29th May 1965;
6, 28th June 1965; 7, 25th July 1965; 8, 28th Aug. 1965; 9, 25th Sept. 1964; 10, 25th Oct. 1964;
11, 28th Nov. 1964; 12, 23rd Dec. 1964.

Numbers are from 120 cores each 38.5 square cm surface area and 18 cm deep. Key: + present; – absent.

App. 1. (cont'd).

Species	Distribution	No. individuals	Sampling occasions 1	2	3	4	5	6	7	8	9	10	11	12
Amblyseius gracilis GARMAN, 1958	cosmopolitan	71	+	+	+	+	+	+	+	+	+	–	–	+
Heteroiphis sp.	Australia, S. America, N.Z.	69	–	+	–	–	+	+	+	+	–	–	–	–
Gamasiphis sp.	Australia, S. America, N.Z.	50	–	–	–	+	+	+	+	+	–	+	–	–
Veigaia serrata WILLMAN, 1935	cosmopolitan	36	–	+	–	+	–	+	+	+	–	+	+	+
Uropodidae	cosmopolitan	23	+	+	+	–	+	+	+	+	+	+	–	+
Hypoaspis sp.	cosmopolitan	5	–	–	–	–	–	–	–	+	–	–	–	+
Pergamasus sp.	cosmopolitan	6	–	–	+	–	–	–	+	+	–	+	–	–
Mesostigmata immatures unidentified		497	+	+	+	+	+	+	+	+	–	–	+	+
Order: Prostigmata														
Cunaxa sp.	cosmopolitan	543	+	+	+	+	+	+	+	+	+	+	+	+
Scutacarus sp.	cosmopolitan	383	–	+	+	+	+	+	+	+	+	+	+	+
Penthaleus sp.	cosmopolitan	314	–	–	–	+	+	+	+	+	–	–	–	–
Pyemotes sp.	cosmopolitan	394	–	+	+	+	+	+	+	+	+	+	+	+
Tydeus sp.	cosmopolitan	3,196	–	+	+	–	+	+	+	+	+	–	–	–
Eupodes sp.	cosmopolitan	497	+	+	+	+	+	+	+	+	+	+	+	+
Rhagidia sp.	cosmopolitan	319	+	+	+	+	+	+	+	+	–	+	+	+
Ledermülleria sp.	cosmopolitan	506	–	+	+	+	+	+	+	+	+	+	+	+
Ereynetes sp.	cosmopolitan	173	–	+	+	+	+	+	+	+	+	+	+	+
Tarsonemidae	cosmopolitan	86	–	+	+	+	+	+	+	–	–	+	–	+
Erythraeidae	cosmopolitan	28	+	+	+	+	–	–	–	–	–	–	–	–
Cheyletidae immatures	cosmopolitan	22	–	–	–	–	–	–	–	–	–	–	–	+
Smaridiidae	cosmopolitan	20	+	+	–	–	–	–	–	–	–	–	–	+
Nanorchestes sp.	cosmopolitan	10	+	–	–	–	–	–	+	+	–	–	–	–
Hypopial nymphs	cosmopolitan	130	–	+	+	+	+	+	+	+	+	+	+	–
Prostigmata (unidentified)		14	–	–	–	+	–	+	+	–	–	–	–	–
Order: Astigmata														
Tyroglyphidae	cosmopoltan	272	+	+	+	+	+	+	+	+	+	+	++	+

Appendix 2 Check list and distribution of Collembola at the Akatarawa site

Species	Distribution	No. Individuals	Sampling occasions											
			1	2	3	4	5	6	7	8	9	10	11	12
Suborder: Arthropleona														
Isotomina thermophila Axelson, 1900)	cosmopolitan	2,852	+	+	+	+	+	+	+	+	+	+	+	+
Protaphorura armata (Tullberg, 1869)	cosmopolitan	2,172	+	+	+	+	+	+	+	+	+	+	+	+
Mesaphorura krausbaueri Börner, 1901	cosmopolitan	1,288	+	+	+	+	+	+	+	+	+	+	+	+
Hypogastrura guthriei (Folsom, 1916)	N. America, N.Z.	1,156	+	+	+	+	+	+	+	+	+	+	+	+
Hypogastrura armata Nicolet, 1841	cosmopolitan	516	+	+	+	+	+	+	+	+	+	−	+	+
Hypogastrura manubrialis (Tullberg, 1869)	cosmopolitan	557	+	+	+	−	+	+	+	+	+	−	+	+
Hypogastrura purpurascens (Womersley, 1928)	cosmopolitan	104	+	+	+	−	+	+	+	+	−	+	−	+
Hypogastrura rossi Salmon, 1941	New Zealand	53	−	−	+	−	+	+	+	−	+	−	+	+
Hypogastrura longispina (Tullberg, 1876)	cosmopolitan	23	+	+	+	−	−	+	+	−	−	−	−	+
Entomobrya nivalis (Linné, 1758)	cosmopolitan	281	+	+	+	+	+	+	+	+	−	+	+	+
Isotomurus palustris (Müller, 176)	cosmopolitan	140	+	+	+	+	+	+	+	−	+	+	+	+
Folsomia candida Willem, 1902	cosmopolitan	91	+	+	+	+	+	+	+	+	+	+	+	+
Isotomiella minor (Schaeffer, 1896)	cosmopolitan	3	−	−	−	−	−	−	−	+	+	−	+	−
Suborder: Neoarthropleona														
Brachystomella parvula (Schaeffer, 1896)	cosmopolitan	745	+	+	+	+	+	+	+	+	+	+	+	+
Friesea mirabilis Tullberg, 1871	Europe, N. America, New Zealand	23	−	−	−	+	+	−	−	+	+	−	−	+
Morulina nov. sp.	New Zealand	16	−	−	−	−	−	+	+	−	−	−	−	+
Suborder: Symphypleona														
Sphaeridia serrata Folsom and Mills, 1938	N. America, Europe, New Zealand	270	−	−	+	+	+	+	+	+	−	+	+	+
Sphaeridia pumilis (Krausbauer, 1898)	cosmopolitan	11	−	+	+	−	−	−	−	−	−	+	−	−
Sminthurinus terrestris Womersley, 1931	Australia, S. Africa, New Zealand	36	+	+	+	−	−	+	−	+	−	−	+	−
Sphyrotheca sphaera Salmon, 1946	New Zealand	18	+	+	+	−	−	−	−	−	−	−	−	−
Arrhopalites caecus (Tullberg, 1871)	cosmopolitan	14	−	+	+	+	+	+	−	−	−	−	−	−
Megalothorax nov. sp.	New Zealand	38	+	+	+	+	+	+	−	+	−	+	+	+
Bourletiella arvalis (Fitch, 1865)	cosmopolitan	11	+	−	+	+	+	−	−	−	−	−	−	+
Sminthurinus lichenatus Salmon, 1946	New Zealand	2	−	+	−	−	−	−	−	−	−	−	−	−
Metakatianna fasciata Salmon, 1944	New Zealand	19	−	−	−	−	−	−	+	−	+	+	−	+

Details as for App. 1. Key: + present; − absent.

Appendix 3 Numbers of the Four Constituent Orders of Acari collected during the Census

(a) Total of 120 cores

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Cryptostigmata	624	1,345	2,551	2,196	4,736	6,191	2,994	2,613	582	1,161	644	877	26,514
Mesostigmata	96	270	262	246	249	610	377	276	39	141	34	136	2,736
Prostigmata	101	501	370	297	473	3,292	1,013	273	45	113	62	95	6,635
Astigmata	25	17	50	32	15	13	34	4	65	5	4	8	272
													36,157

(b) Percentages of total Acari and total microarthropods

	Per cent total Acari	Per cent total microarthropods	No. per sq. metre
Cryptostigmata	73.3	57.1	57,380
Mesostigmata	7.6	5.9	5,921
Prostigmata	18.4	14.2	14,359
Astigmata	0.7	0.5	590
		77.7	78,250

The figures for each month are the total from 10 cores (each 38.5 sq. cm. surface area × 18 cm deep).

Appendix 4 Numbers of the Three Constituent Suborders and main Families of Collembola collected during the census

(a) Total of 120 cores

		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Arthropleona	Onychiuridae	172	114	78	99	306	1.131	588	569	41	124	83	101	3.406
	Hypogastruridae	66	65	105	512	208	505	432	277	34	54	72	91	2.421
	Entomobryidae	117	37	45	49	7	6	3	1	—	1	4	13	283
	Isotomidae	185	136	393	407	737	83	179	92	96	184	273	184	2.991
Neoarthropleona		37	50	112	144	60	123	66	39	19	12	43	79	784
Symphypleona		19	39	23	122	53	77	12	34	4	12	15	54	464
														10.349

(b) Percentages of total Collembola and total microarthropods

		Per cent tot. Collembola	Per cent tot. microarthropods	No. per sq. metre
Arthropleona	Onychiuridae	33.0	7.3	7.370
	Hypogastruridae	23.3	5.2	5.240
	Entomobryidae	2.7	0.6	612
	Isotomidae	29.0	6.4	6.474
Neoarthropleona		7.5	1.7	1.696
Symphypleona		4.5	1.1	1.005
			22.3	22.397
Mean number microarthropods per sq. metre				100.647

The figures for each month are the total from 10 cores (each 38.5 sq. cm surface area × 18 cm deep).